Soil characteristics of a riparian mitigation wetland (billabong) six years after creation

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Abstract

Soil color, bulk density, and organic matter content were measured in the ORW billabong wetland in fall 2002. Soil depth from 0 to 16 cm was studied and examined with respect to vegetation/elevation zones (upland, transitional, deep-water) and proximity to the inflow. Bulk density was highest in the upland vegetation zones (1.34 ± 0.16 g/cm^3) and lowest in the deep-water zones (0.61 ± 0.42 g/cm^3). Organic matter levels were highest in the deep-water zone than in the upland and transitional vegetation zone as well. Organic matter levels were also found to be higher in the northern end of the wetland where river water enters the wetland and greater productivity has occurred. Greatest differences in organic matter (4.8-15.2 %) and bulk densities (0.31-0.91 g/cm^3) occurred in deep water wetland zones.

Introduction

The construction of wetlands, especially for mitigation purposes under Section 404 of the Clean Water Act, has created the need for increased research in order to understand the functions of these systems (Cole and Shafer, 2002). The Clean Water Act makes it necessary for wetlands that are lost due to filling or dredging to be replaced in order to allow for a "no net-loss" of wetlands. However, the question is often raised as to whether or not created wetlands are doing the job of replacing wetland functions in addition to replacing wetland area (Campbell et al., 2002). Soil characteristics are often used to determine the success of these mitigation wetlands, creating a serious need for detailed information regarding the formation of hydric soils and the processes that occur within them over time. Bishel-Machung et al. (1996) and numerous other studies have provided recent data that adds to our understanding of soils within created wetlands, but detailed analyses of soils in created wetlands over time have not been well documented (Cole and Brooks, 2000). Soils play a very important part in the ability of a wetland to perform certain functions such as nutrient retention, providing habitat for living organisms, and sediment sinks (Stolt et al., 2000; Richardson and Brinson, 2001). Additionally, soils are important for the cycling of nutrients, including nitrogen, phosphorus, and carbon within a wetland (Mitsch and Gosselink, 2000). The chemical make up of water that exits a wetland is, in effect, fairly dependent upon the specifics of these nutrient cycles in wetland soil (Richardson and Brinson, 2001). Because of these functions, the genesis of hydric soils and the characteristics of those soils need to be studied in order be able to completely understand constructed wetland ecosystems.

There are several identifiable components of hydric soils, which include soil color, organic matter content, and oxidation-reduction features. Although not all of these components are necessary to indicate hydric soil, at least one of them are found in hydric soils, with a few exceptions (Tiner, 1999). The relatively dark color of hydric soils is a result of anaerobic conditions, which reduces many compounds in the soil resulting in the exposure of the soil matrix, which is generally black or gray in color (Mitsch and Gosselink, 2000). Net primary productivity often dominates over decomposition rates in anaerobic conditions, leading to an accumulation of organic matter in the soil within many wetlands (Craft, 2001). Increased organic matter further contributes to the darkening of soil and also tends to cause bulk densities to decrease (Collins & Kuehl, 2001). However, soil conditions are also affected by many other factors, which must be taken into consideration. Wetland hydroperiod, nutrient availability, chemical cycling, climate, biota, and many other factors can have pronounced effects upon wetland soils (Craft, 2001).

In 1996, a mitigation wetland known as the "billabong" (Fig. 1) was created at the Olentangy River Wetland Research Park (ORW) (Mitsch, 1993) to mitigate the loss of 1.1 ha of wetlands at a Fairfield County, Ohio, landfill. In this study, soil analyses were conducted in order to compare soil characteristics to vegetation zones, hydrologic pathways, and also to add to the existing data that has been collected for this site. Soil analysis consisted of soil color determinations, bulk densities, and organic matter content within samples collected at two opposite ends of the site. The soil data for each sampling location is compared to other samples as well as data from previous soil date from the billabong.

Methods

Site description

The ORW is located in Columbus, Ohio, just north of the Ohio State University campus and is located on the Olentangy River floodplain, which consists of soil that is derived from glacial outwash. The soils at the time of construction of the

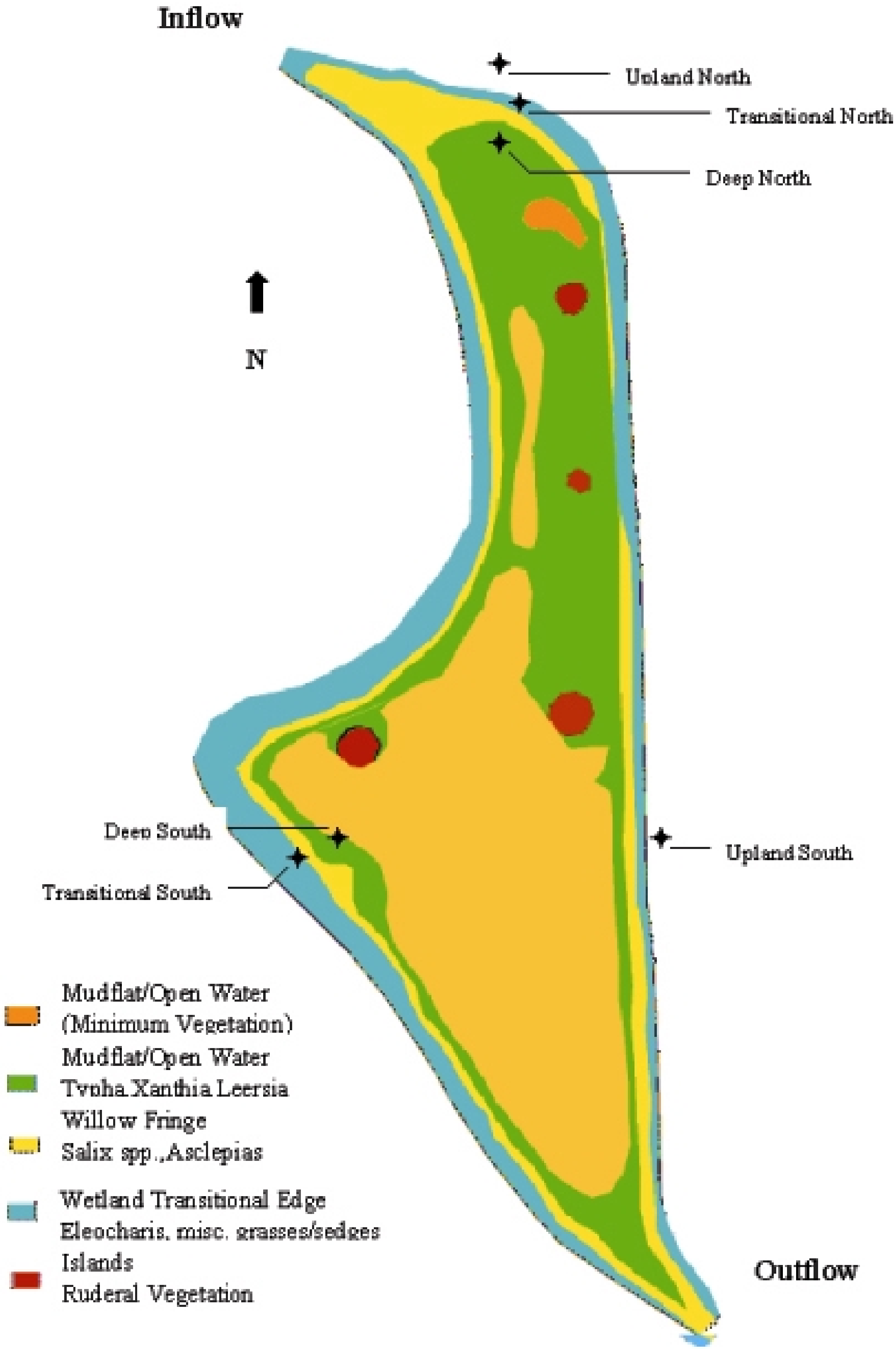

Figure 1. Vegetation map and sampling points in the billabong for this study.

mitigation wetland (Fig. 1) were determined to be of the Ross and Eldean series, which consist of silt loam, silt clay, and clay loams (Mitsch, 1993). This created riparian wetland, known locally as the billabong, is fed by river water during periods of bankfull discharge, as well as groundwater that enters into the northern end of the wetland. This wetland has a hydroperiod that is characteristic of most floodplain wetlands in Ohio, and thus is wet during the winter and spring while experiencing dry periods during late summer.

Field sampling

Soil sampling for this study was conducted on 22 October 2002. Soil samples were collected along two transects at the billabong. The first transect was at the north end of the billabong approximately 50 m from the inflow and the second transect was located at the south end along the widest portion of the billabong. For each transect, three different sampling points were selected from the surrounding upland to the deep-water portion of the billabong (Fig. 1). For each sampling area, one sample was taken from an upland area that is saturated only during periods of exceptionally high water levels. This zone was adjacent to the wetland boundary, but consisted of mostly upland plants and grasses. A second sample was taken within the transitional zone that consisted primarily of facultative wetland vegetation and is usually saturated for a short period time after a heavy rain event. A third soil sample was collected from the deeper wetland area that was composed almost entirely of obligate wetland vegetation and is saturated for much of the year. In the northern end of the wetland, this deep-water zone was composed of almost entirely of a dense stand of *Typha* sp. and *Sparganium* sp. In the southern portion of the wetland, this deep-water sample was taken from an area that consisted of sporadic *Eleocharis* sp., *Scirpus* sp., and mud flats.

At each sample point, soil was extracted from the ground using a shovel spade and using a knife, carefully cut into a 2 x 3 cm and 16 cm deep section. Because of compaction, standard soil probes were not effective for use in this study. Soil color was evaluated in the field using a Munsell soil chart at each sampling point. Soil samples were then placed into plastic bags and refrigerated until laboratory analysis was conducted.

Laboratory techniques

Soil samples were processed according to the methods presented by previous soil research at the ORW (Nairn and Mitsch, 1996, Gilbert et al, 1999, Broennum et al, 2001). Samples were placed in a drying oven at 105 degrees C until constant mass was achieved. From this, bulk densities were calculated by using the dry weight obtained after drying and the soil volume collected in the field (2 x 3 x 16 cm). Secondly, each sample was ground and passed through a 1-mm sieve. Next, samples were weighed and then combusted in a dry muffle furnace at 550 degrees C for approximately one hour. Post combustion weight was obtained and then calculations were performed to determine the percent organic matter.

Results

Hues varied between 2.5Y and 10YR, but were not dependent upon sampling location. Additionally, soil values were found to be 3 in the deep and transitional sample points but a value of 4 was found in both upland samples. A chroma of 2 was found in all samples except the upland north sample, which showed a chroma of 4 (Table 1).

Bulk densities for the billabong showed a trend of higher values in upland areas and lower values for the samples taken in deeper zones (Figure 2). This trend was observed in both the north and south transects of the billabong, although a steeper gradient was noticed in the upland sampling area. In addition, the maximum and minimum values of the bulk densities taken in the northern portion of the billabong were lower than those taken in the southern portion, with a range of 0.31-1.22 g/cm^3 in the north and 0.91-1.45 g/cm^3 in the south.

Organic matter percentages within the billabong were found to be higher in the north transect than those in the

Table 1. Soil color for billabong soils-2002

North or South	Vegetation Zone	Hue	Value	Chroma
North	Upland	10YR	4	4
North	Transition	10YR	3	2
North	Deep	2.5Y	3	2
South	Upland	10YR	4	2
South	Transition	2.5Y	3	2
South	Deep	10YR	3	2

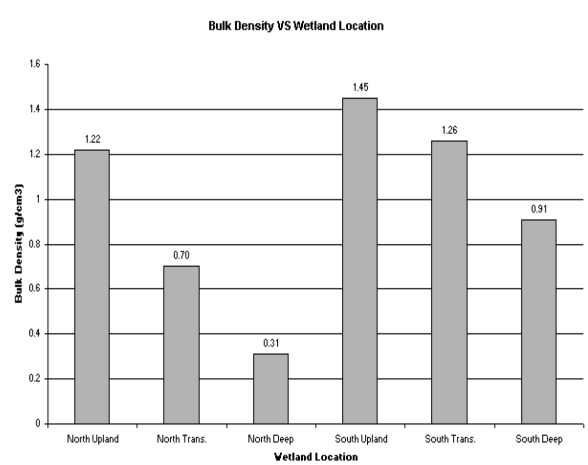

Figure 2. Bulk densities for the billabong in 2002. Three sampling points were located in each end of the wetland within three different vegetation zones: upland, transitional, and deep-wetland.

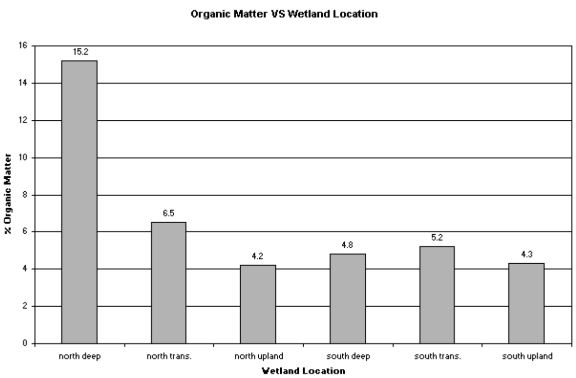

Figure 3. Organic matter in the billabong in 2002. Three sampling points were located in each end of the wetland within three different vegetation zones: upland, transitional, and deep-wetland.

south transect (Figure 3). Additionally, there was a wider range of values found for organic matter along the north transect of the wetland (4.2% to 15.2%) than in the south (4.3% to 5.2%). The deep north sampling point contained an organic matter percentage of 15.2 while the deep south point showed a value of 4.3. In addition, bulk density in the deep north sample was 0.31 g/cm^3 while the southern deep sample was 0.91 g/cm^3.

Discussion

The soils in the upland north sample of the billabong showed a chroma value of 4 while the rest of the billabong samples were shown to have a chroma value of 2. We expected both upland samples to have a chroma higher than those within the wetland do, so hydrologic or geomorphologic explanations may be required in order to explain the differences in these sample chromas. Additionally, even though these two samples were taken within the same vegetation zone surrounding the wetland, elevations were not recorded at the sampling sites. As a result, the sample taken in the southern upland portion of the billabong could be exposed to anaerobic conditions more often than the northern upland sample.

There were interesting differences found in soil bulk densities concerning the different sampling locations. There was a noticeable change in bulk densities when moving from upland to deep wetland zones. The accumulation of organic matter in the deeper wetland areas of the billabong explains the differences in bulk density. Organic matter percentages were considerably higher in the deep-water zones of the wetland compared to the transitional and upland samples. Anaerobic conditions occur for a longer period of time in the lower elevations than those in more upland areas due to a longer hydroperiod. As a result, decomposition is reduced in this area and organic matter has accumulated faster than in the higher elevations, causing soil bulk densities to decrease.

The minimum and maximum values within the ranges of bulk density were higher at the north end of the billabong than in the south. We noted that the northern end of this wetland was the point where water enters the wetland and vegetation appears to be more productive and denser than comparable areas at the south end (Bouchard and Mitsch, 1999). It is likely that the nutrient levels at the northern end of the billabong are higher than in the southern end due to uptake by the vegetation. Svengsouk and Mitsch (2001) have shown that higher nutrient levels often result in a less diverse community of tolerant plant species. The lower level of bulk density in the southern end can be explained by the fact that lower nutrient levels have lead to a lower amount of standing biomass. This has lead to a lower rate of organic matter accumulation, and thus a lower soil bulk density. The most notable differences in both bulk density and organic matter were in the deep wetland samples. Higher plant biomass and nutrient levels in the northern sampling points are most likely important factors in causing the large differences between inflow and outflow.

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